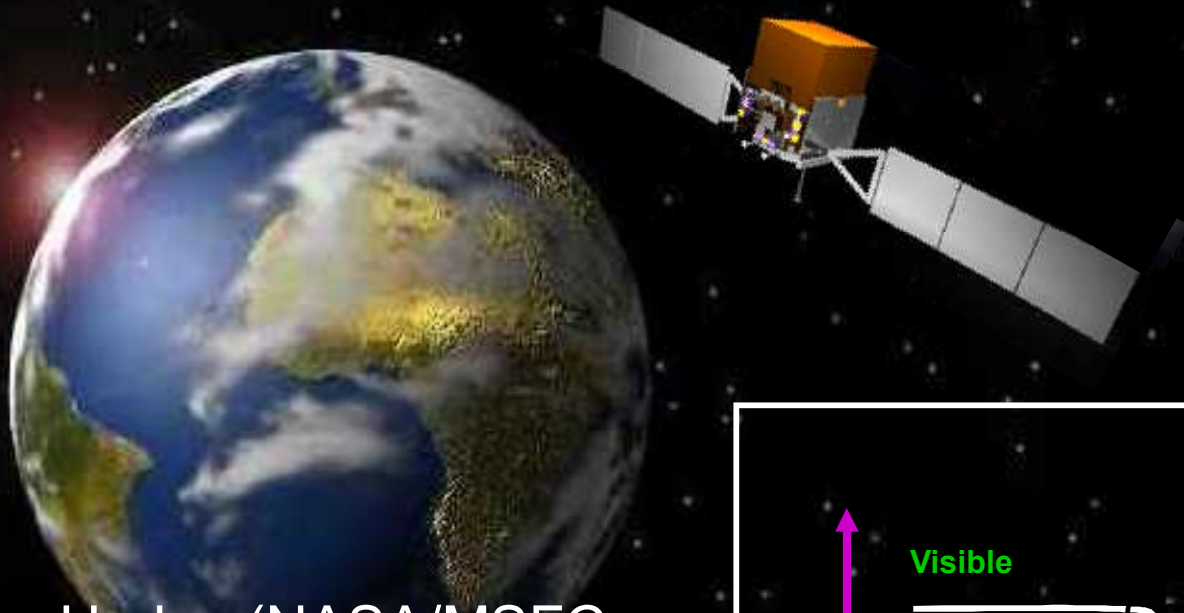


All-Sky Earth Occultation Observations with the Fermi Gamma Ray Burst Monitor

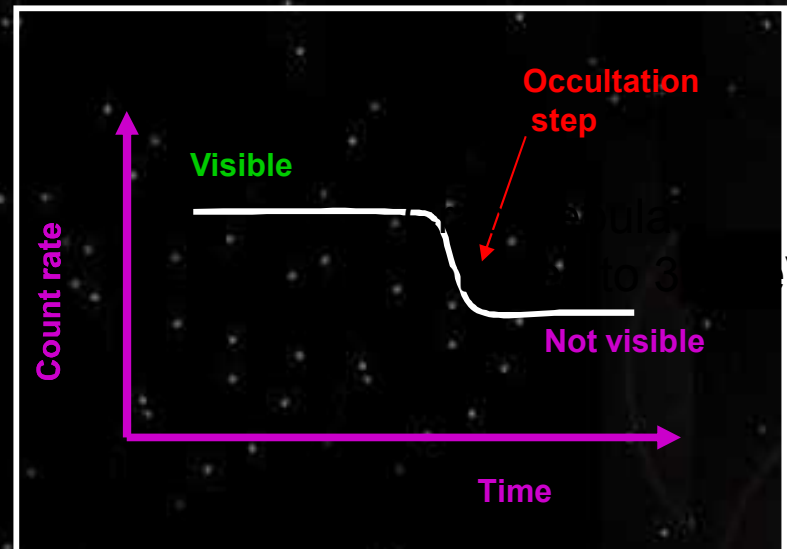
C.A. Wilson-Hodge, G. Case, M. Cherry, J. Rodi, M. Finger, A. Camero-Arranz, V. Chaplin, V. Connaughton, E. Beklen, R.H. Haynes, P.N. Bhat, M. Briggs, R. Preece for the GBM Earth Occultation Team

Using the Gamma Ray Burst Monitor (GBM) on-board Fermi, we are monitoring the hard X-ray/soft gamma ray sky using the Earth occultation technique. Each time a source in our catalog is occulted by (or exits occultation by) the Earth, we measure its flux by determining the change in count rate due to the occultation. Currently we are using CTIME data with 8 energy channels spanning 8 keV to 1 MeV for the GBM NaI detectors and spanning 150 keV to 40 MeV for the GBM BGO detectors. Our preliminary catalog consists of galactic X-ray binaries, the Crab Nebula, and active galactic nuclei. We will present early results. Regularly updated results can be found on our website <http://gamma-ray.nsstc.nasa.gov/gbm/science/occultation>.

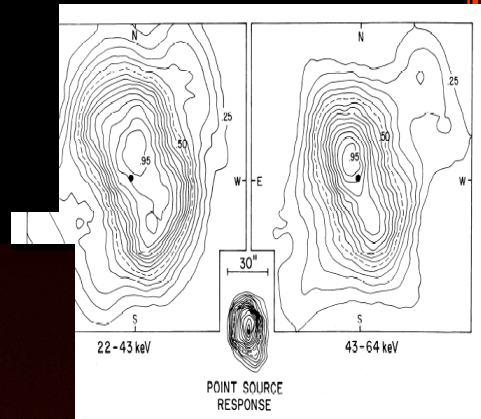
All-Sky Earth Occultation Observations with the Fermi Gamma-ray Burst Monitor



C.A. Wilson-Hodge (NASA/MSFC),
G. Case, M. Cherry, J. Rodi (LSU), M.
Finger (USRA), A. Camero-Arranz (NSSTC),
V. Chaplin, V. Connaughton, P.N. Bhat, M.
Briggs (UAH), E. Belken (METU), R.H.
Haynes (NASA Academy) for the GBM Earth
Occultation Team



Brief History of Occultation Techniques

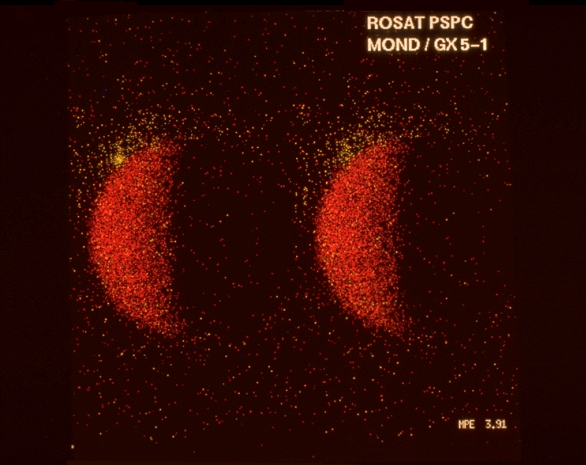


Lunar Occultations

- 1960s and 1970s
 - X-ray extent and structure of Crab Nebula
 - 1977 GX 9+1 located
- 1990s
 - 1990-92 Observations of dust scattering halos with ROSAT
 - 1993-94 lunar Crab measurements with BATSE

Earth Occultations

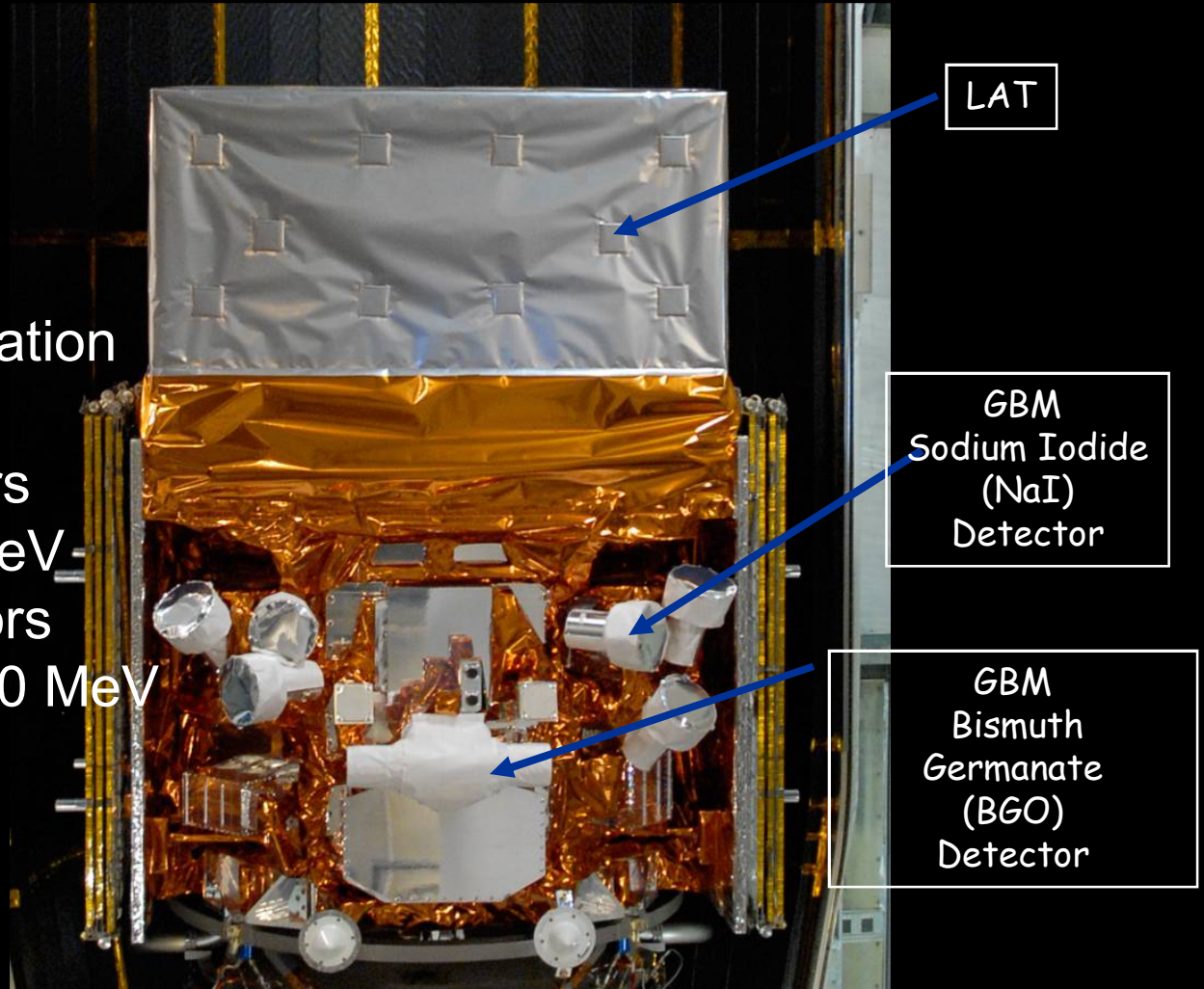
- 1991-2000 monitoring with BATSE



★ 2008- Earth Occultation measurements with GBM

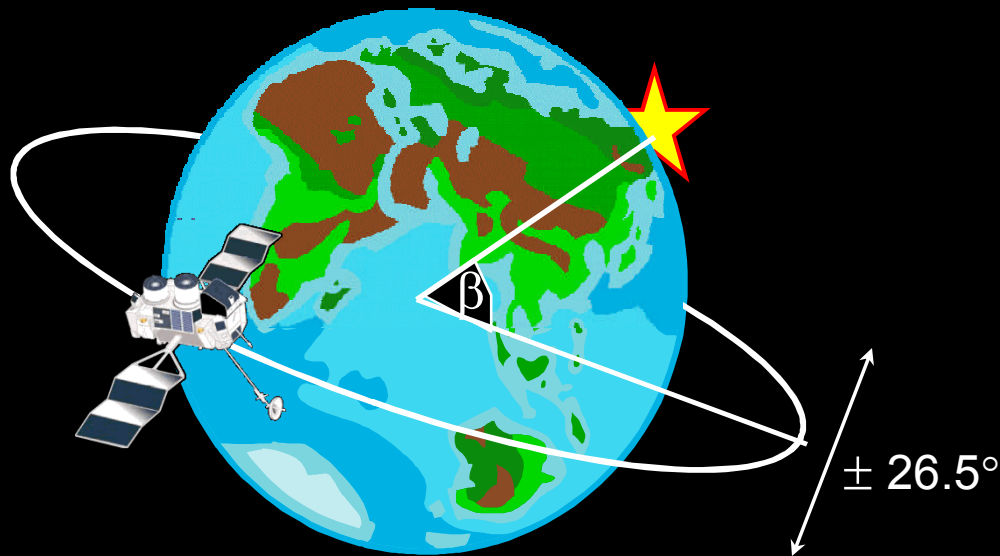
Fermi GBM

- Fermi
 - 550 km orbit
 - 28.5 deg inclination
- GBM
 - 12 NaI detectors
 - 8 keV - 1 MeV
 - 2 BGO detectors
 - 150 keV - 40 MeV



Occultation Coverage

The diameter of the Earth seen from Fermi is $\sim 140^\circ$, so roughly 30% of the sky is occulted by the Earth at any one time. The precession of the orbit, caused by the oblateness of the Earth means that the entire sky is occulted every ~ 55 days.

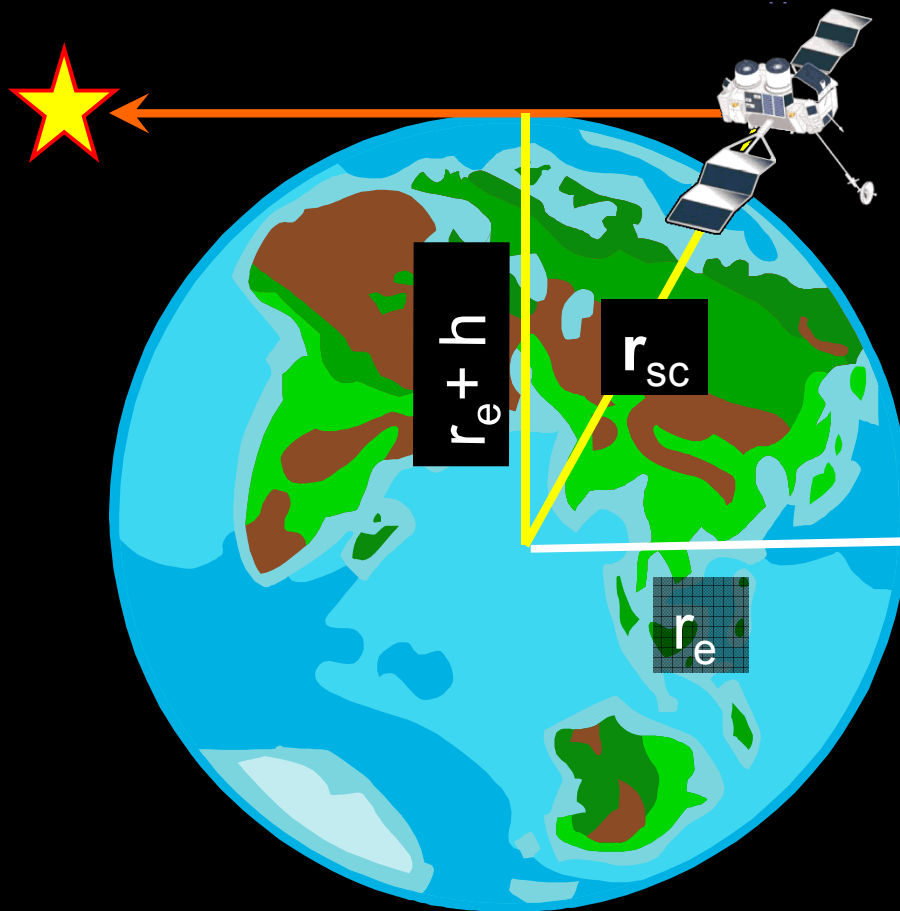


Fermi Orbital Information

- Altitude ~ 565 km
- Period ~ 96 min
- Inclination $\sim 26.5^\circ$

β , the 'occultation angle', is measured at the geo-centre between a source crossing the Earth's limb and the orbital plane.

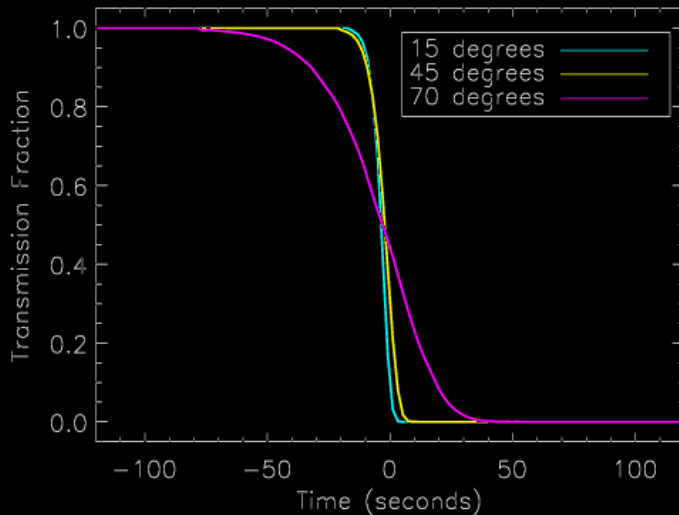
Occultation Geometry



- Earth Radius
 - $r_e = 6378.136$ km
- Spacecraft position
 - $\vec{r}_{sc} = (x, y, z)$
- Source direction
 - $\vec{\Omega} = (\Omega_x, \Omega_y, \Omega_z)$
- $h(s)$ = Altitude of the line of sight to a source at a distance s from the spacecraft

Atmospheric Transmission

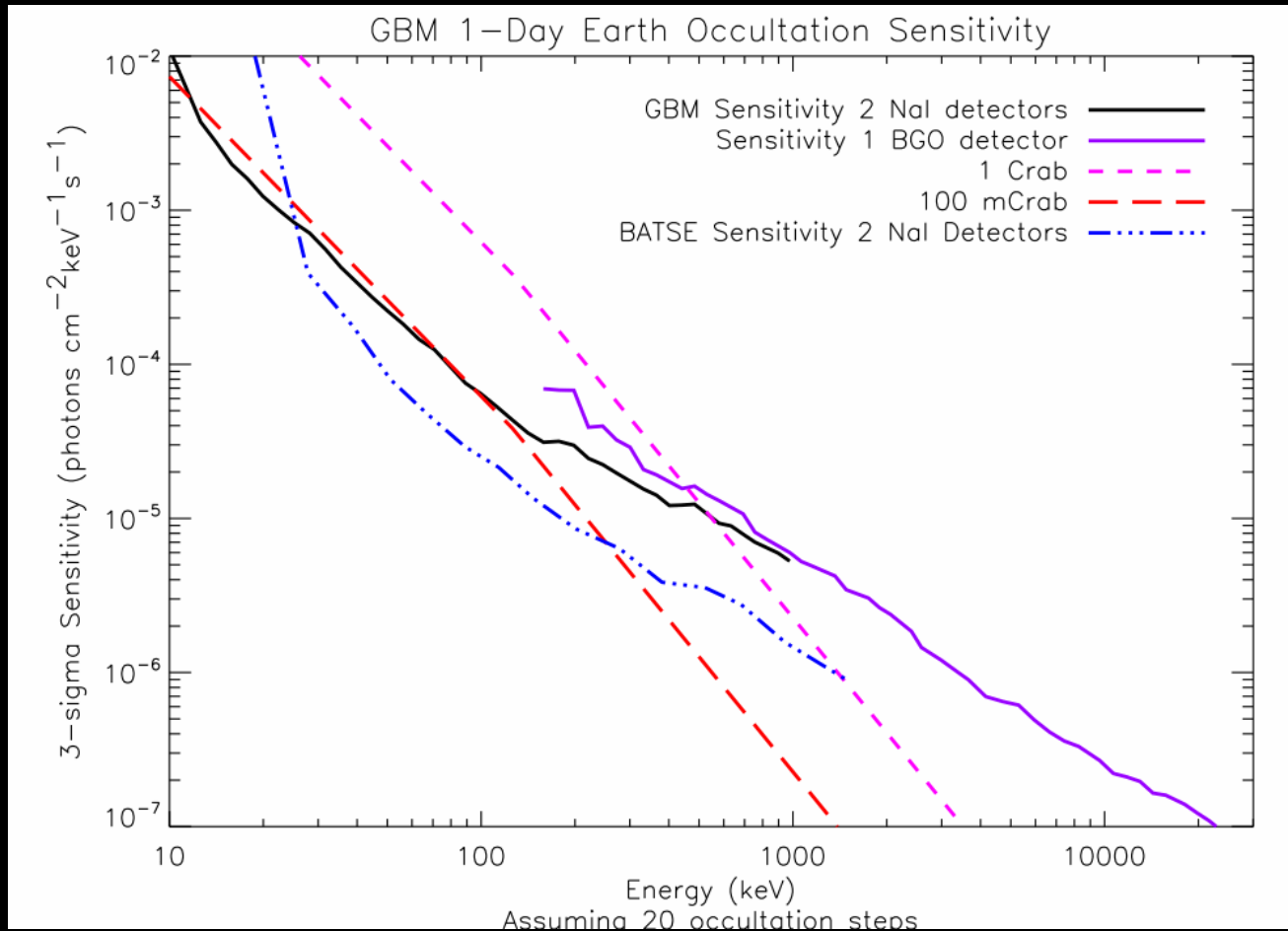
Earth occultation steps are not simple step functions.



At $h=70$ km, $T(t)=0.5$ for 100 keV photons

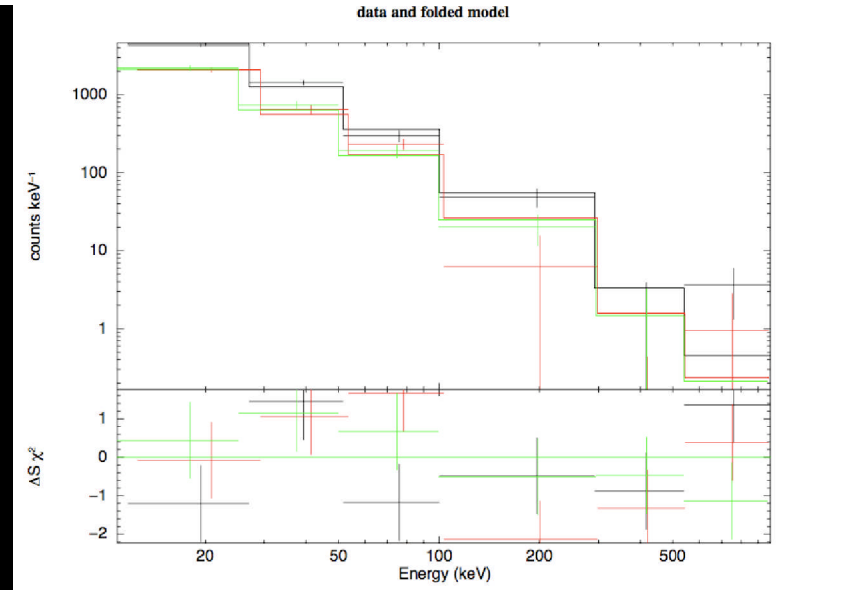
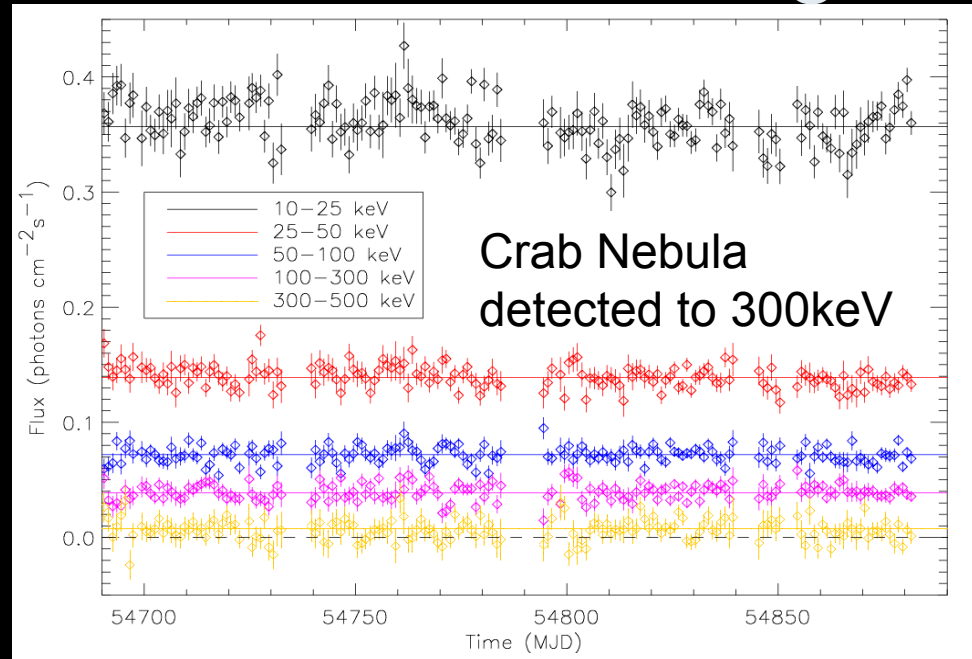
- The step shape depends on energy and occultation angle.
- The steps are modeled as $T(t) = \exp[\mu(E) A(h)]$, where:
 - $\mu(E)$ = mass attenuation coefficient of gamma rays in air.
 - $A(h)$ = air mass along the line of sight at a given altitude $h(t)$.

GBM Earth Occultation Sensitivity

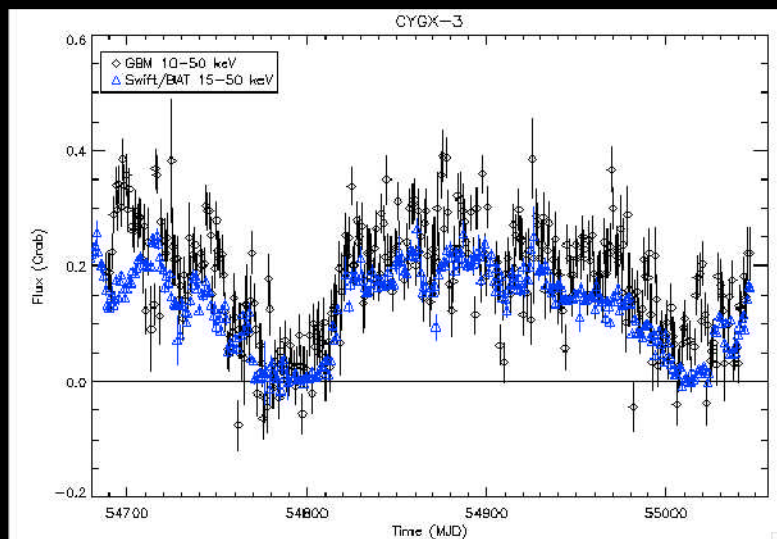
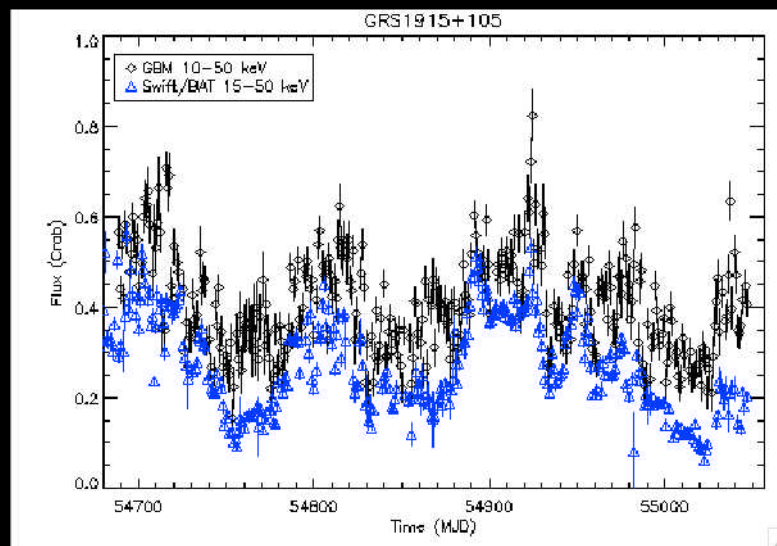
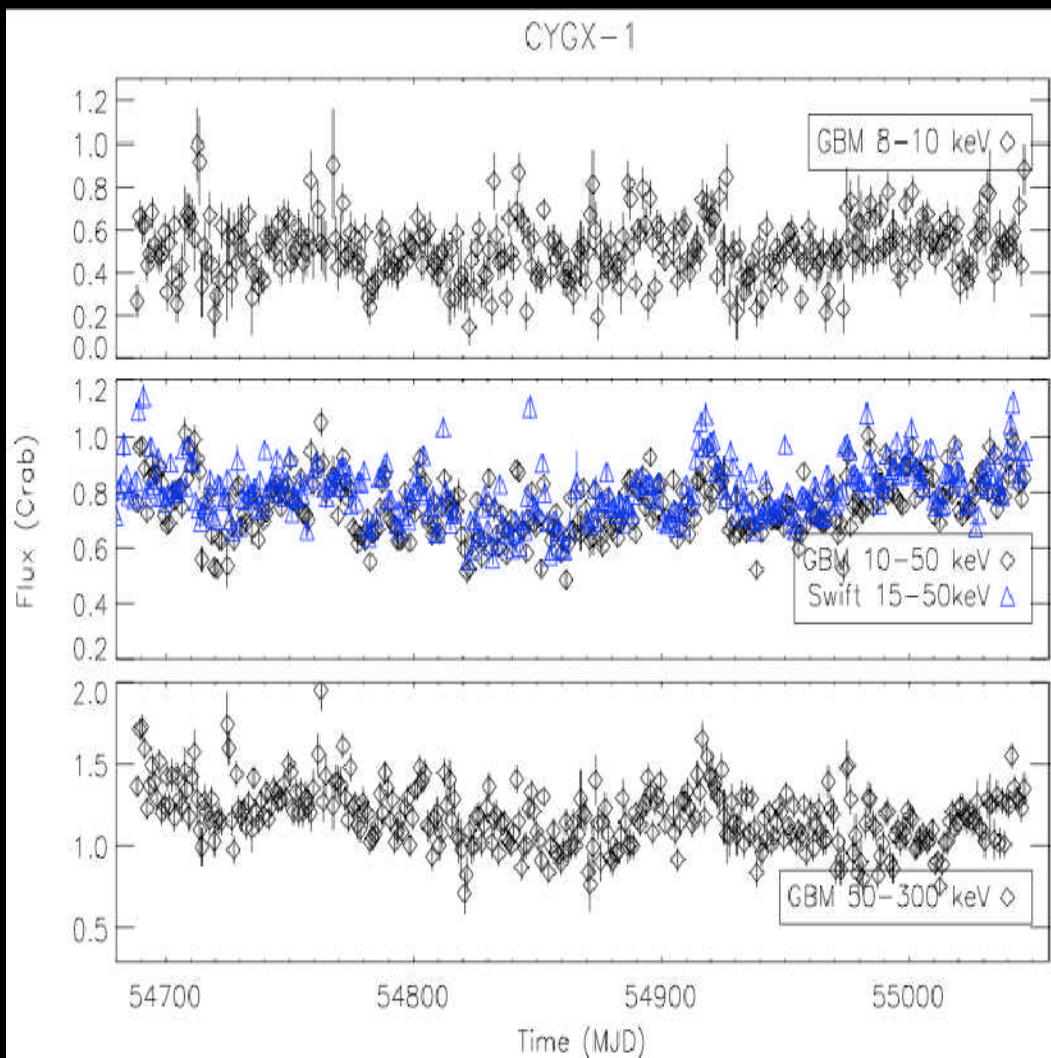


GBM Earth occultation monitoring

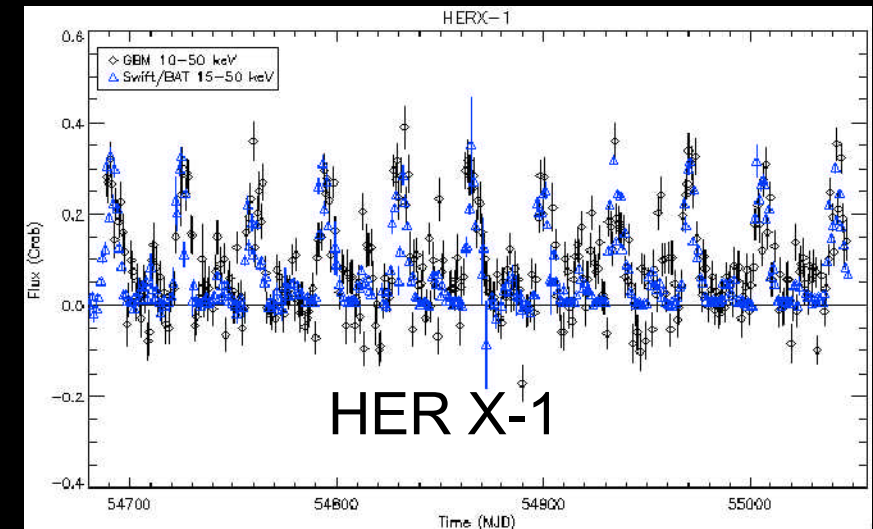
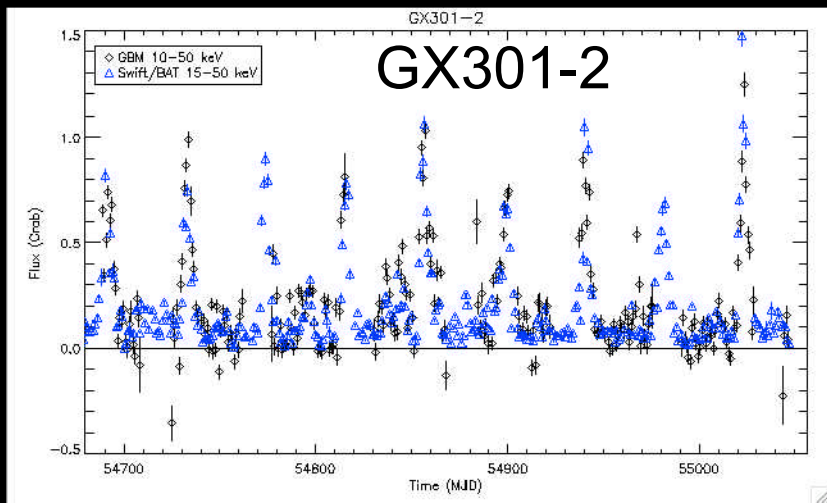
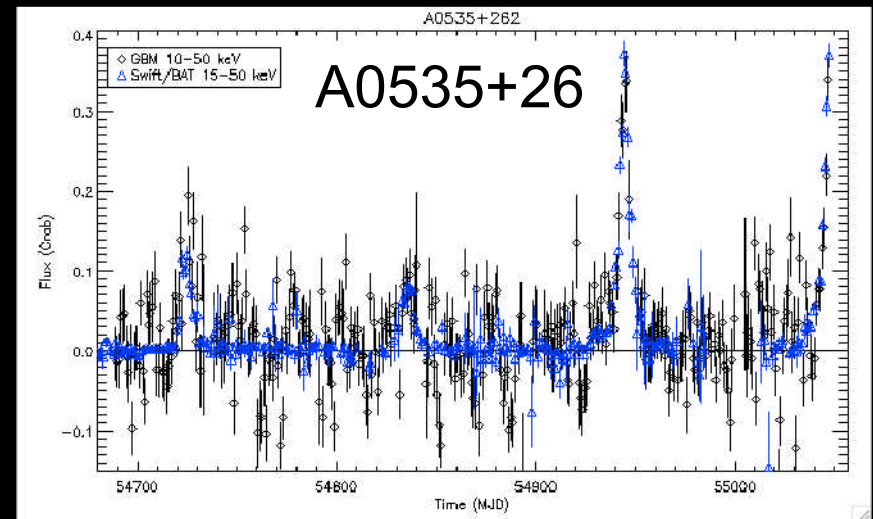
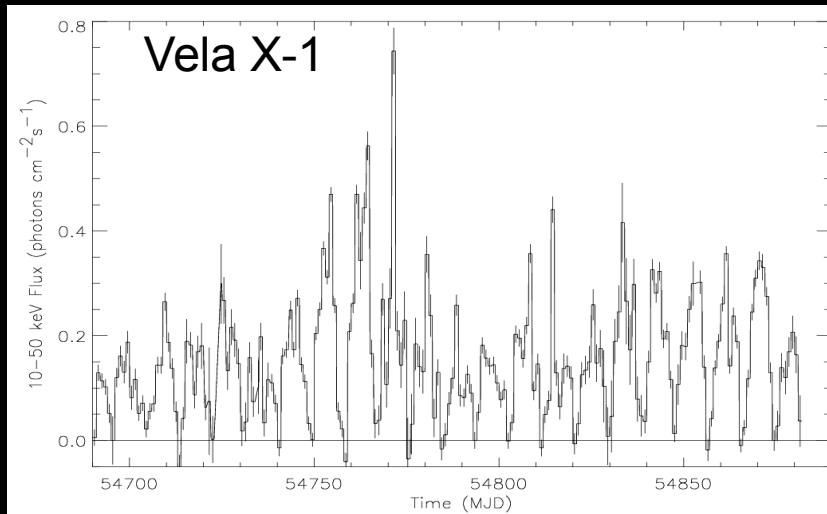
- Initial catalog of 31 sources
 - X-ray binaries
 - Crab
 - Cen A
- Sources will be added to catalog
- CTIME data (8 channel, 256 ms time resolution)
- Fit a 4 minute window around each step
- Include bright sources occulting in window
- Optimizing bright source inclusion



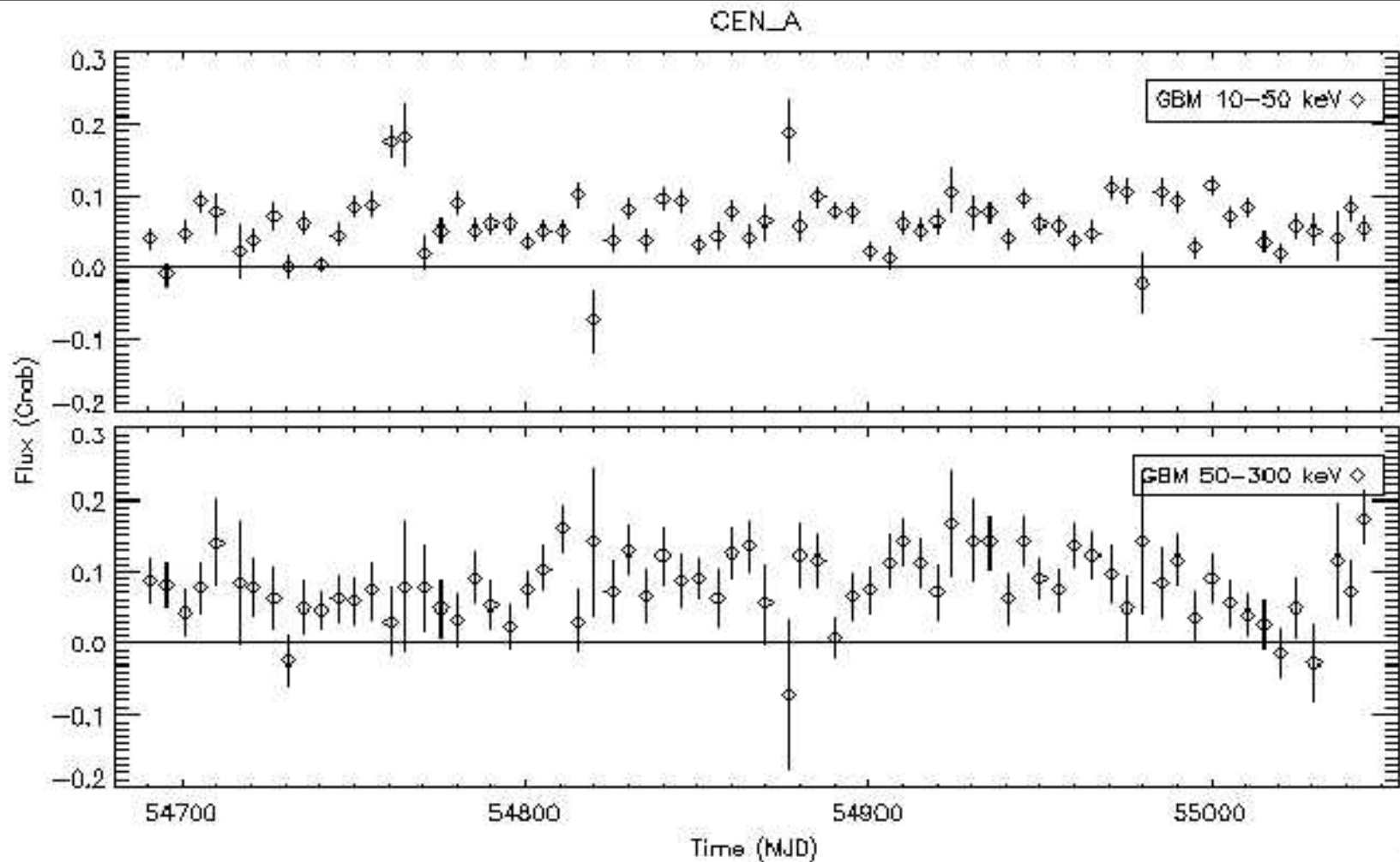
Black Hole Binaries with GBM and Swift/BAT



Accreting Pulsars with GBM Earth Occultation



AGNs with GBM Earth Occultation



Summary

- GBM Earth occultation technique is working nicely
- Source monitoring is getting underway
- Agreement with Swift/BAT is good
- Additional energy coverage above and below Swift/BAT range
- Watch our website for new lightcurves
- <http://www.batse.msfc.nasa.gov/gbm/science/occultation/>